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DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 83-31

Canada

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ABSTRACT

The fabrics Nomex and Evolution 3 were examined and their physical properties relevant to use in tent liners were compared. In general, Nomex was found to be superior to Evolution 3 for use in tent liners. The Nomex samples were lighter, less voluminous, stronger, more flame retardant and had a lower water vapour resistance than the Evolution 3 samples. Evolution 3 absorbed less water than did Nomex. The poor flammability properties of the Evolution 3 was its principal defect. The insulating benefits of tent liners made of either material were found to be comparable.

RÉSUMÉ

Les tissus Nomex et Evolution 3 ont été examinés, et leurs propriétés physiques permettant leur emploi dans la fabrication de doublures de tentes, comparées. En général, le Nomex a été jugé supérieur au Evolution 3 pour cet usage. Les échantillons de Nomex étaient plus légers, moins volumineux, plus solides, plus ignifuges et plus perméables à la vapeur d'eau que ceux du Evolution 3. Ce dernier a absorbé moins d'eau que le Nomex. Les médiocres propriétés ignifuges du Evolution 3 ont constitué son principal défaut. Le qualité de l'isolation procurée par les doublures de tentes faites de ces deux tissus a été jugée comparable.

1.0 Introduction

The virtual flood of new fabrics on the market has made it difficult for the tent designer to chose the most suitable material for a particular application. The designer must read a large number of promotional brochures in order to extract the useful technical information required to make the correct choice.

DCGEM, the agency responsible for Canadian Forces (CF) tentage design, is investigating the possibility of using one of these new fabrics, Evolution 3 [1], to replace Nomex [2] which is currently used in the liner of the CF 10 Man Arctic Tent.

In support of this investigation, work was carried out at DREO to determine pertinent properties of Evolution 3 and Nomex, to see which is better suited for use in CF tent liners.

This report gives the general physical properties, the flammability properties, load-elongation properties at various temperatures and the results of field tests of Nomex and Evolution 3 liners in CF 10 Man Arctic Tents.

2.0 General Physical Properties

Nomex is an aramid, a flame-resistant nylon. The Nomex fabric used in this study was a 1x1 plain weave fabric with a nominal weight of 0.105 kg/sq.m. (DCGEM # D-80.001.018/SF-001).

Evolution 3 is a non-woven polypropylene composite, consisting of two outer layers of spunbond filament polypropylene with an inner layer of melt-blown filament polypropylene, held together by spot heat sealing. The nominal weight of the Evolution 3 sample used in this study is 0.135 kg/sq.m. (DCGEM # X82.461).

Table 1 lists the general physical properties of the two materials which were measured at DREO. Descriptions of the test proceedures are given in Appendix A.

Table 1. General Physical Properties Of Nomex And Evolution 3. (Mean values with standard deviation in brackets).

Property	Nomex		Evolution 3	
Thickness(cm)	0.030	(0.001)	0.117	(0.001)
Count (threads/cm):				
Warp	35			
Weft	27			
Mass (kg/sq.m.)	0.111	(0.017)	0.147	(.004))
Moisture Regain (%)	6.15	(0.71)	1.60	(0.26)
Water Adsorption (%)				
1 minute	119	(3)	54	(19)
5 minutes	125	(4)	42	(7)
15 minutes	126	(1)	38	(2)
Water Vapour Resistance (mm air)	0.81	(0.19)	1.20	(0.44)

The Nomex fabric is considerably thinner than the Evolution 3 fabric (approximately 75% thinner) and its weight per unit area is approximately 25% less than that of Evolution 3. For a tent such as the CF 10 Man Arctic Tent, which requires a liner of approximately 43.25 sq.m., the weight of a Nomex liner would be 4.8 kg while an Evolution 3 liner would weigh 6.4 kg. It is expected that the light transmission through the Evolution 3 is less than the Nomex due to the greater thickness of the Evolution 3, however, the facilities required to verify this assumption were not available at DREO.

The amounts of water absorbed by each fabric when they are immersed in water are significantly different. Using the values for the Water Absorption after fifteen minutes, Nomex would absorb 0.14 kg of water per square metre of material while Evolution 3 would absorb only 0.06 kg of water per square metre of material (57% less than Nomex). For the tent liner size described above, a saturated Nomex liner would absorb 5.97 kg of water and a saturated Evolution 3 liner would absorb 2.85 kg of water. In contrast, the amounts of water absorbed from the air are extremely small. From the measurements of the Moisture Regain at 65% Relative Humidity and 21 C, it is calculated that Nomex absorbs only 0.007 kg of water per square metre and the Evolution 3 absorbs 0.002 kg of water per square metre. The amount of water vapour absorbed by each fabric is less than the variation of each fabric's weight per square metre, and as such is of negligible importance in contributing to the overall weight of the tent liner.

The water vapour resistance of the Nomex material is approximately 33% lower than that of the Evolution 3. The water vapour resistance per unit thickness of the Nomex is, however, greater than the Evolution 3. The thinness of this Nomex fabric produces the lower absolute water vapour resistance given in Table 1. The greater porosity of Evolution 3 gives it

the superior water vapour resistance per unit thickness. (Using the densities of aramid fibres polypropylene and the mass per unit area given in Table 1, it was found that Nomex has a 40% fibre content by volume while Evolution 3 has only 9% fibre content by volume). The differences in the water vapour resistances will only be significant, given the small quantity of water absorbed from the air, when the temperature of the liner is greater than the freezing point of water. If the liner temperature is below the freezing point of water, any condensation will subsequently freeze, producing a frost build up on the liner, which may inhibit further vapour transmission through the fabric. It is expected that this process will occur more slowly in the Nomex due to its lower water vapour resistance. It is not known whether or not this difference would be significant over time scales of the order of several hours or several days, both of which are typical for tent use in cold weather climates.

2.2 Combustion Properties

Nomex and Evolution 3 were tested for their flammability properties using the Vertical Burning Test, Method 27.1-M77 [4] and the Surface Burning Test, Method 27.2-M77 [4]. The Vertical Burning Test was modified slightly by clamping the fabric samples along the sides rather than at the top. This was done to constrain the fabric, as it would be in use, so that should the fabric shrink, it would not shrink away from the flame in an unrealistic manner. Each test was recorded on videotape so that it could be reviewed as necessary.

Table 2. Literature Information On The Temperature Characteristics Of Nomex And Polypropylene [3]. (Temperatures in degrees Celsius).

Characteristic	Nomex	Polypropylene
Softens		140 - 166
Melts		160 - 177
Decomposes	371	288

2.2.1 Vertical Flame Test

The Nomex samples shrank slightly towards the flame but they remained intact (Figure 1a). An afterglow of approximately eight seconds was observed but this was limited to the charred region of the samples only. No flashing or afterflame were observed. The char length was approximately 7.5 cm.

(a)

(b)

Figure 1: Typical Vertical Flame Test Results for

(a) Nomex
(b) Evolution 3

When the Evolution 3 samples were placed in the flame, they rapidly shrank away from the flame, leaving a hole in the fabric (Figure 1b). No afterflame or afterglow was observed, however, some dripping of melted fabric occurred. The length of the melted region was approximately 11.5 cm.

2.2.2 Surface Burning Test

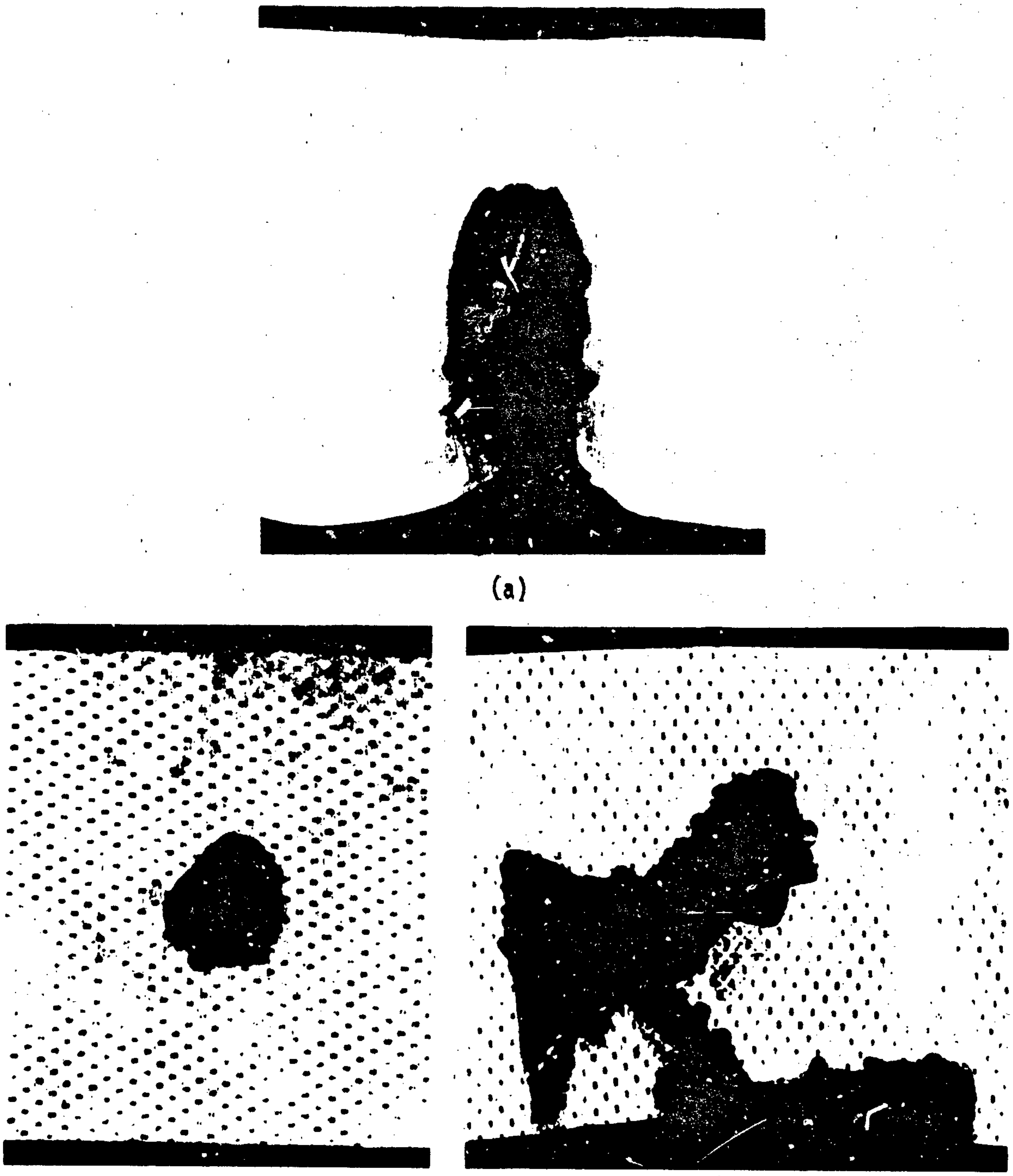
This test is perhaps more appropriate for testing the flammability of a tent-liner material because the orientation of the material, and the manner in which the flame impinges upon the material, would be similar to actual situations.

Nomex was found to be "Moderately Flame Resistant" according to the definitions outlined in Method 27.2-M77. The material charred at the edge to a width of approximately 40 cm. No afterflame or afterglow was observed. Again the material remained intact (Figure 2a), shrinking slightly towards the flame. No dripping or flashing occured.

Evolution 3 was deemed to be "Not Flame Resistant". Large holes formed as the material melted away from the flame (Figure 2b). Some afterflame was observed with all samples. In every case, dripping of melted material occured, and in one case the material supported its own combustion (Figure 2c). In this case, drops of burning and molten material were observed for several seconds as the flame advanced over the material.

2.3 Load-Elongation Properties At Various Temperatures

The strength tests were carried out in accordance with Method 9.1 - M77, Breaking Strength Of Fabrics - Strip Method (Constant Time To Break Principle) [4] using 2.5 cm wide samples. Evolution 3 was tested in the "warp" direction only at temperatures below 20 C as it was found that there was very little difference in the breaking characteristics of Evolution 3 when it was tested in the "warp","weft" and "bias" directions at 20 C, (93, 85 and 93 N respectively).



(a)

(b) (c)

Figure 2: Typical Surface Burning Results for

(a) Nomex
(b,c) Evolution 3

The tests were carried out in an environmental chamber which was fitted onto an Instron, Model 1102. The chamber was cooled to 0, -20 and -40 C by placing solid carbon dioxide in the bottom of the chamber. For the 20 C tests, the specimens were broken immediately. For the other temperatures, the specimens were cold-soaked for fifteen minutes before being broken. It took about two minutes of the fifteen minute periods for the chamber to return to 0 C after opening and closing the chamber door for the insertion of the specimen, three minutes at -20 C and five minutes at -40 C. In order to prevent the specimens from slipping, the jaws of the Instron were lined with emery paper.

The results of the tests are given in Table 3. Yield points were evident for both materials in all tests. None of the samples had secondary yields points. Typical load-elongation curves for each fabric at the four temperatures are given in Figure 3.

The results for both the Nomex and the Evolution 3 are similar to those found previously 5 , namely that in general:

(1) the breaking strength increases as temperature decreases,
(2) the percentage elongation at break increases at 0 C and then decreases with decreasing temperature,
(3) the initial modulus increases with decreasing temperature.

It has been hypothesized 5 that the increase in the percentage elongation at break for 0 C is due to the presence of moisture in the samples which acts as a lubricant, allowing the yarns and filaments to slip over each other more easily as the load is applied.

All values for Nomex are of the same magnitude as those found for conventional nylons 5 . The peculiar shape of the load-elongation curve at high loads for Nomex warp at 20 and 0 C is due to the threads at the edge of the specimens breaking first, rather than a sudden, clean break across the entire specimen.

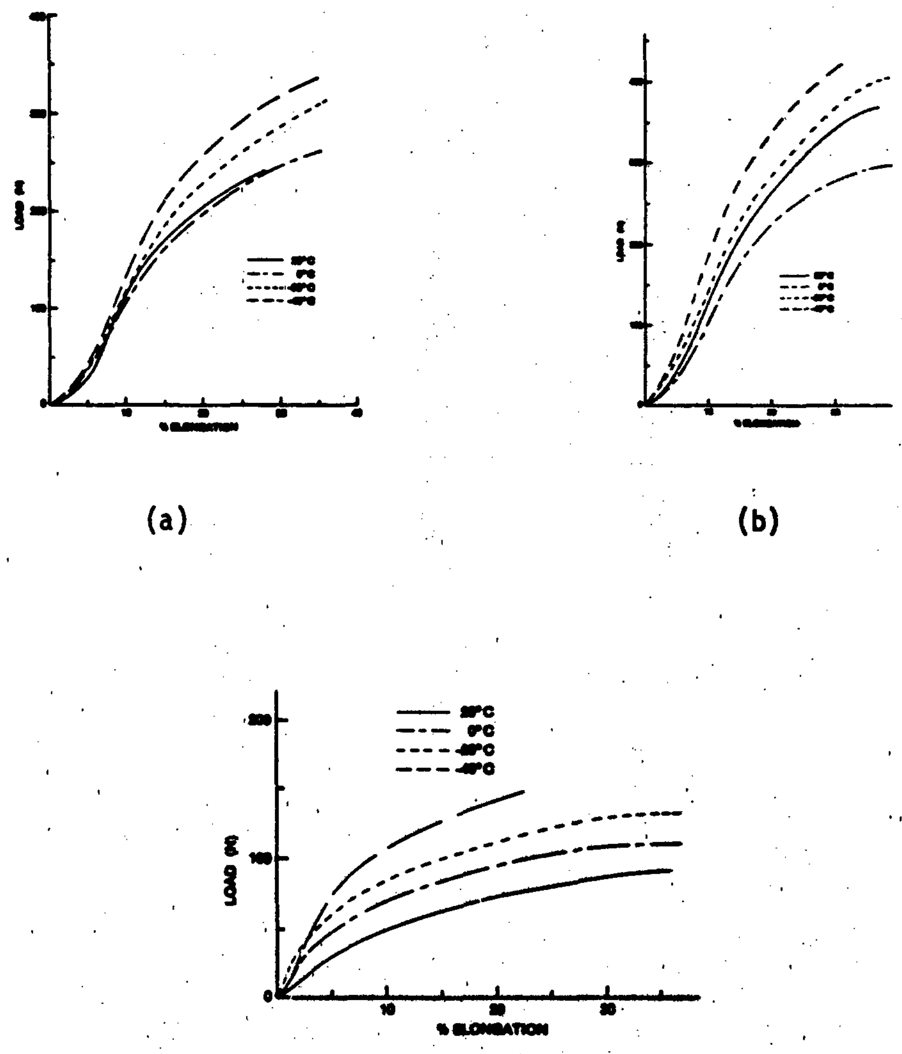
From Table 3, it can be seen that Nomex has a greater breaking load than does Evolution 3. The data indicates that Nomex is 2.8 to 3.9 times stronger than Evolution 3 in the warp direction, and 2.3 to 2.6 times stronger than Evolution 3 in the weft direction for the temperatures given.

Both fabrics stretched approximately the same amount for temperatures greater than -40 C. At -40 C, the elongation under load of the Evolution 3 decreased dramatically from the previous temperatures, and stretched substantially less than did the Nomex (29% less). This means that Nomex is more flexible at low temperatures, and should therefore pack easier. Ease of packing depends upon Young's Modulus, however, it is not known at this time whether or not the difference between the materials is significant.

Table 3. Strength Characteristics of Nomex and Evolution 3

Characteristic	Nomex								Evolution 3			
	Warp				Weft							
Temperature (C)	20	0	-20	-40	20	0	-20	-40	20	0	-20	-40
Breaking Load (N)	365	307	400	423	240	262	302	338	93	111	129	133
cv	2	4	3	4	4	3	13	1	10	8	14	10
Percentage Change		-16	30	6		9	15	21		20	16	3
Total Change (%)		16				40				43		
Percent Elongation	36	38	37	31	28	37	35	35	36	39	33	22
cv	6	11	3	10	7	5	17	3	11	8	18	18
Percentage Change (%)		6	-3	-16		32	-5	0		8	-15	-33
Total Change (%)		-14				25				98		
No. of Specimens	5	5	5	5	5	4	6	5	6	6	6	6

cv is the coefficient of variation.



(a) (b) (c)

Figure 3: Typical Load-Extension Curves for

(a) Nomex Weft
(b) Nomex Warp
(c) Evolution 3

2.4 Field Tests

A comparison of the effectiveness of Nomex and Evolution 3 tent liners was made at the DREO Tent Testing Facility. CF 10 Man Arctic Tents were used with a conventional Nomex liner and one with an Evolution 3 liner. Heat was supplied by forced convection, electric heaters. The test extended over several weeks and encompassed a variety of weather conditions.

Listed in Table 4 is the mean "Relative Temperature per Watt Of Heat Input To The Tent" for each of the lined tents. This value is calculated from equation 1:

$$T' = (\sum_{i} Ti * Vi)/(V*Q) \qquad (1)$$

where,

T' = Relative Temperature Per Watt Of Heat Input
Ti = local temperature at point "i" (Figure 4)
Vi = local incremental volume around point "i" (Figure 4)
V = the total tent volume
Q = the heat input to the tent

The incremental volumes were assigned to each thermistor site so that the horizontal and vertical boundaries of the volumes fell midway between the sensors (Figure 4). Temperatures were found to vary only slightly with distance from the pole, except near the wall of the tent. The vertical variation in temperature was more significant as can be seen in Figure 4.

The volume weighted mean tent temperature was normalized to the heater output to negate any variations in the amount of heat supplied to the tent. Heat was supplied to the tents at the following rates: Nomex lined, 2285 W; Evolution 3 lined, 3061 W. The resultant parameter (T') is similar to a thermal resistance.

It was found that the Nomex and Evolution 3 liners performed quite similarly. This is to be expected if, as hypothesised [8], tent liners derive most of their thermal resistance from the thermal boundary layers. From Table 4, it can be seen that the ratio of T' of Evolution 3 to the T' of the Nomex varies from 92% to 108%, indicating little difference between the performances of Evolution 3 and Nomex as tent liners. It has been found [8] that the addition of a Nomex liner to the 10 Man Arctic tent can increase the T' of the tent by 60% to 100%. Thus, it is apparent that the variations in T' for either of the two lined tents is small in comparison with the increase of T' by the addition of a liner to an unlined tent. Variations in T' for different experiments is due to different ambient conditions.

Table 4. Relative Temperature Per Watt Of Heat Input For
10 Man Arctic Tents Lined With Nomex Or Evolution 3.

Experiment Number	T' (Nomex) (C/W)	T' (Evolution 3) (C/W)	T' (Evol. 3) / T' (Nomex)
049	0.01020	0.00970	0.95
050	0.01015	0.00954	0.94
051	0.00906	0.00833	0.92
053	0.00906	0.00879	0.97
060	0.01002	0.00960	0.96
061	0.00797	0.00764	0.96
062	0.00985	0.00918	0.93
067	0.00766	0.00817	1.07
068	0.00775	0.00839	1.08
081	0.00976	0.01040	1.07

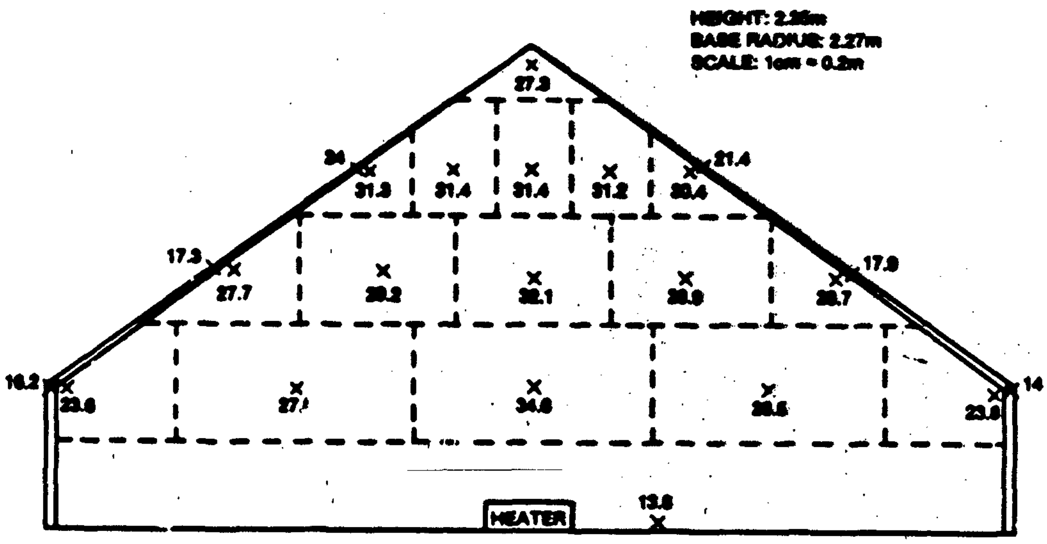


Figure 4: Typical Volume Assignment and Temperature Distribution in the 10 Man Arctic Tent

(Volume Between Liner and Tent Wall Neglected)
(Temperature Referenced to Ambient)
(X - Indicates Sensor Position)

3.0 Conclusion

The positive, negative and inconsequential attributes of the Nomex and Evolution 3, as found in this investigation, are given in Table 5. These are listed with the assumption that they are each being considered for use as a tent liner.

Table 5. Attributes of Nomex and Evolution 3.

Attribute	Nomex	Evolution 3
Positive	- 25% lighter - thinner, smaller packed volume - 33% lower water vapour resistance - moderately flame resistant - remains intact when exposed to flame - 2.5 to 4 times stronger	- 52% lower water absorption - thicker, possibly less light transmission
Negative	- higher water adsorption - thinner, more light transmission	- not flame retardant - material melts and drips when exposed to flame - heavier - thicker, larger packed volume - not as strong - marked decrease in flexibility between -20 and -40 C
Inconsequential	- water vapour absorption is very small - approximately the same elongation under load for temperatures above -20 C - thermal insulating values are approximately the same	

As Nomex out-performs Evolution 3, based on these results, Nomex would be the preferred choice over Evolution 3 for use in tent liners. The most damaging attribute of the Evolution 3 is its unsatifactory and potentially dangerous flammability characteristics.

Acknowledgement

The author would like to thank P.Dolhan, M.Dewar and Dr.R.Crow for their contributions to this report. This study was supported by DCGEM under DCGEM Task# 36.

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Appendix A.

Test Methods For Data Quoted In Text.
(Test methods were taken from Reference 4 unless otherwise noted.)

Data	Test Method
Fabric Thickness	Method 37 - M77
Fabric Mass	Method 5.A - M77
Thread Count	Method 6 - M77
Water Vapour Permeability	Reference 7
Moisture Regain	Method 3 - M77
Water Absorption	Reference 6
Vertical Burning Test	Method 27.2 - M77
Surface Burning Test	Method 27.2 - M77
Breaking Strength	Method 9.1 - M77

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Security Classification

DOCUMENT CONTROL DATA – R & D

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1. ORIGINATING ACTIVITY Defence Research Establishment Ottawa Department of National Defence Ottawa, Ontario, CANADA K1A 0Z4	2a. DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. DOCUMENT TITLE

A COMPARISON OF NOMEX AND EVOLUTION 3 FOR USE IN TENT LINERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
TECHNICAL NOTE

5. AUTHOR(S) (Last name, first name, middle initial)

Cain, B.

6. DOCUMENT DATE DECEMBER 1983	7a. TOTAL NO. OF PAGES 15	7b. NO. OF REFS 8

8a. PROJECT OR GRANT NO. 14B	9a. ORIGINATOR'S DOCUMENT NUMBER(S) DREO TN 83-31
8b. CONTRACT NO.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)

10. DISTRIBUTION STATEMENT
Unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY DCGEM

13. ABSTRACT

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DSIS
77-066

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Security Classification

KEY WORDS

Tent
Liner
Material Properties,
~~Flammability~~
Strengthks, and
Thermal Resistance.
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